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(54) **ENGINE CONTROL SYSTEMS AND METHODS FOR ACCELERATOR PEDAL TIP-OUT**

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| ***F02D 41/12*** | (2006.01) |
| ***F02D 37/02*** | (2006.01) |
| *F02D 41/00* | (2006.01) |
| *F02D 13/02* | (2006.01) |

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(58) **Field of Classification Search**

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USPC ..................................... 701/102, 54, 51, 110

See application file for complete search history.

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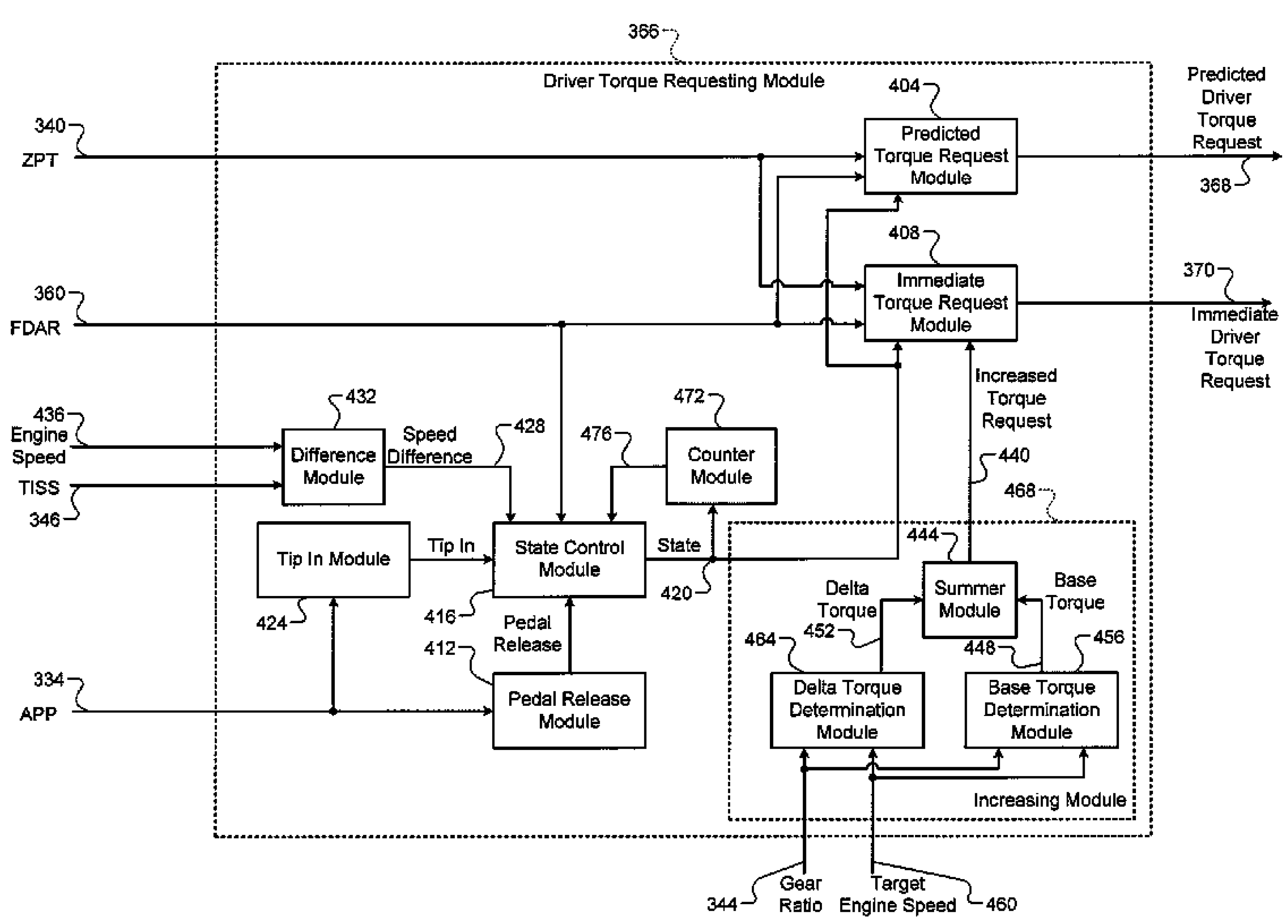
*Primary Examiner* — Mahmoud Gimie

(57) **ABSTRACT**

A difference module determines a difference between an engine speed and a transmission input shaft speed. A state control module sets a signal to a first state when a driver releases an accelerator pedal and selectively transitions the signal from the first state to a second state when the difference is less than zero. An immediate torque request module decreases an engine torque request when the signal is in the first state and selectively increases the engine torque request when the signal is in the second state. At least one of: a spark control module that selectively adjusts spark timing based on the engine torque request; and a fuel control module that selectively adjusts fueling based on the engine torque request.

**20 Claims, 6 Drawing Sheets**



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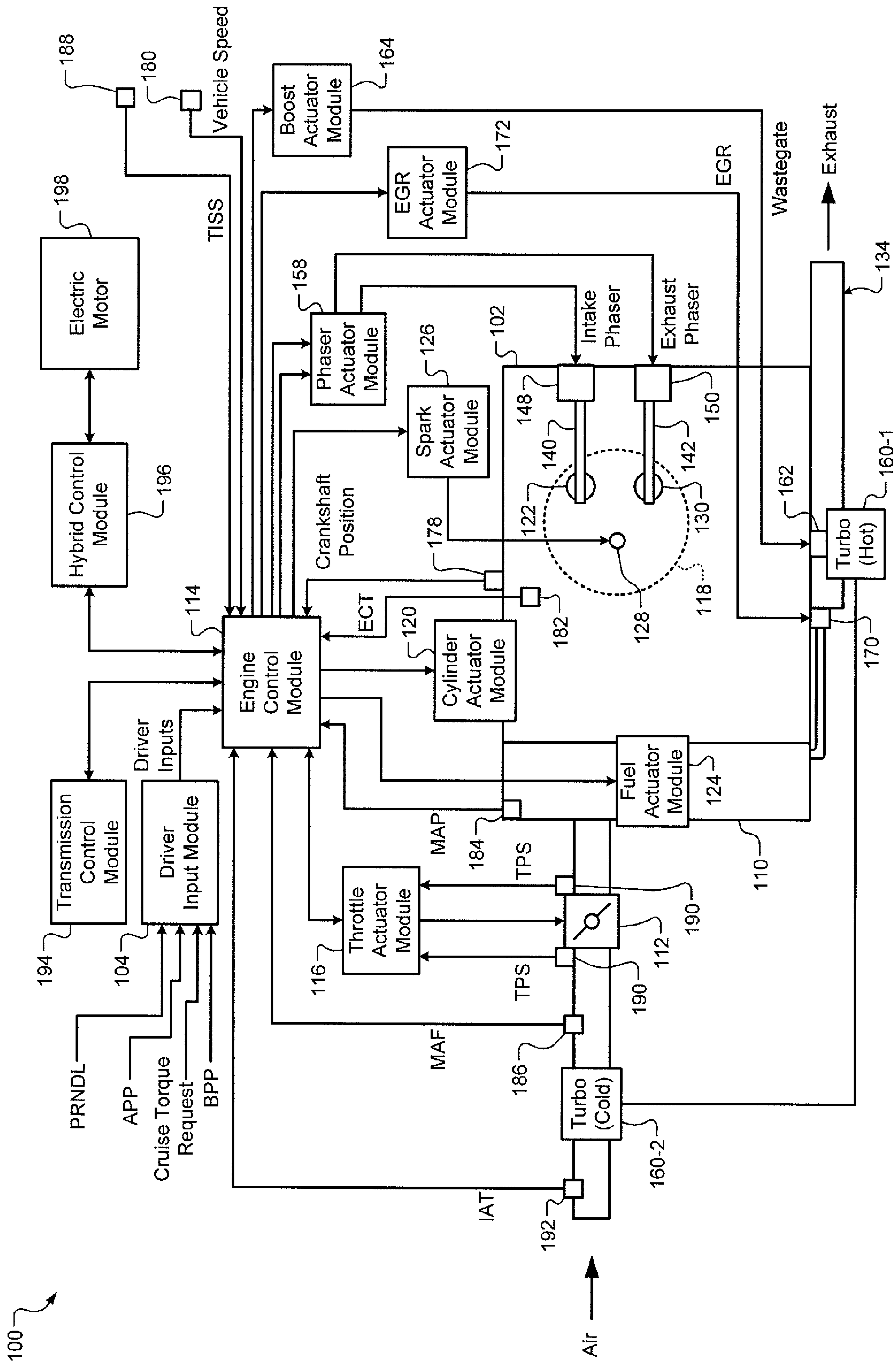

100
Air
IAT
192
Turbo (Cold)
160-2
MAF
186
TPS
190
112
Throttle Actuator Module
116
MAP
184
Fuel Actuator Module
124
110
Cylinder Actuator Module
120
Engine Control Module
114
ECT
182
Crankshaft Position
178
Spark Actuator Module
126
Phaser Actuator Module
158
EGR Actuator Module
172
Boost Actuator Module
164
Intake Phaser
Exhaust Phaser
102
148
150
140
142
122
130
128
118
Turbo (Hot)
160-1
162
170
134
EGR
Wastegate
Exhaust
Vehicle Speed
180
188
TISS
Electric Motor
198
Hybrid Control Module
196
Transmission Control Module
194
Driver Input Module
104
Driver Inputs
PRNDL
APP
Cruise Torque Request
BPP
FIG. 1

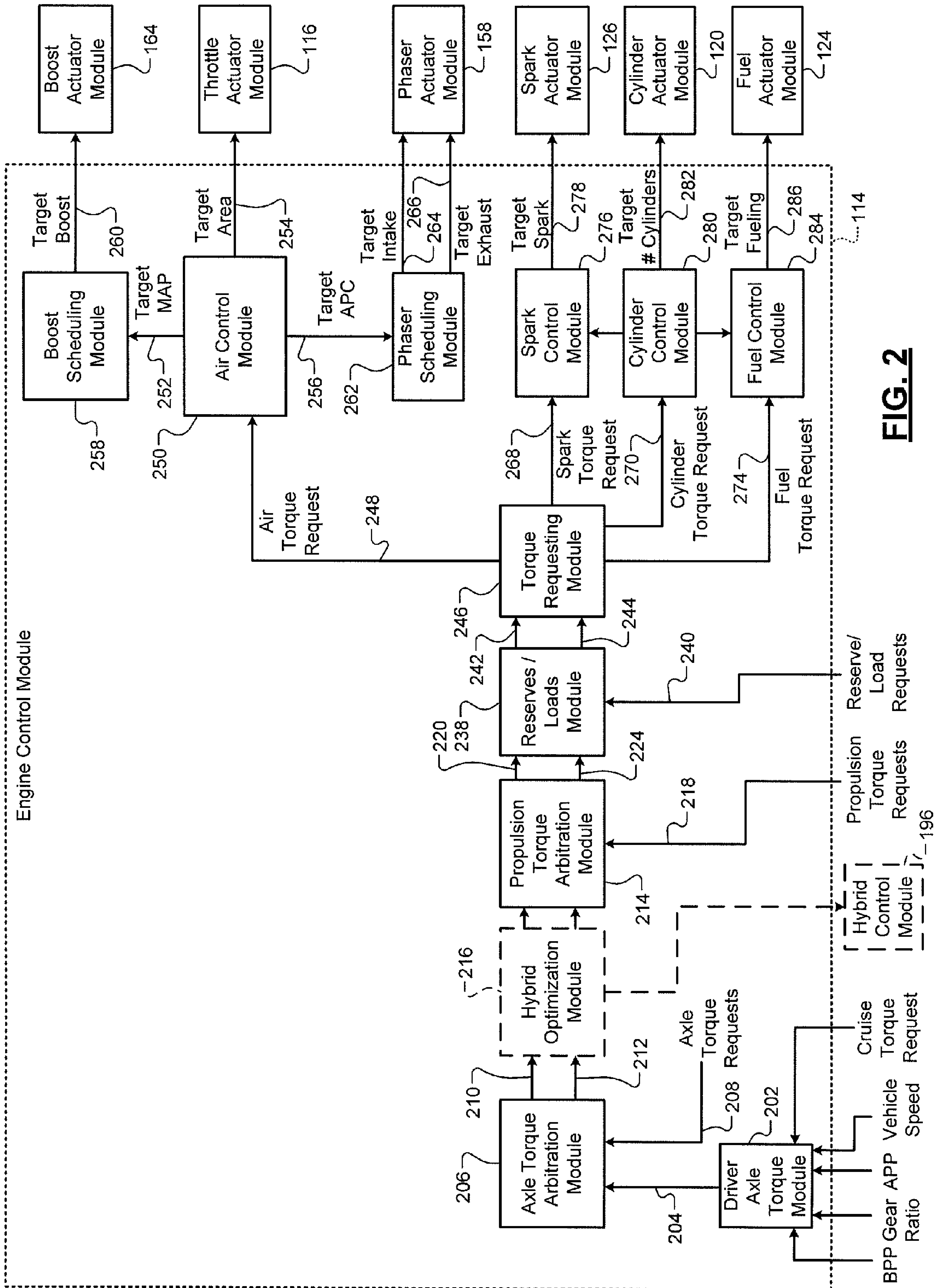
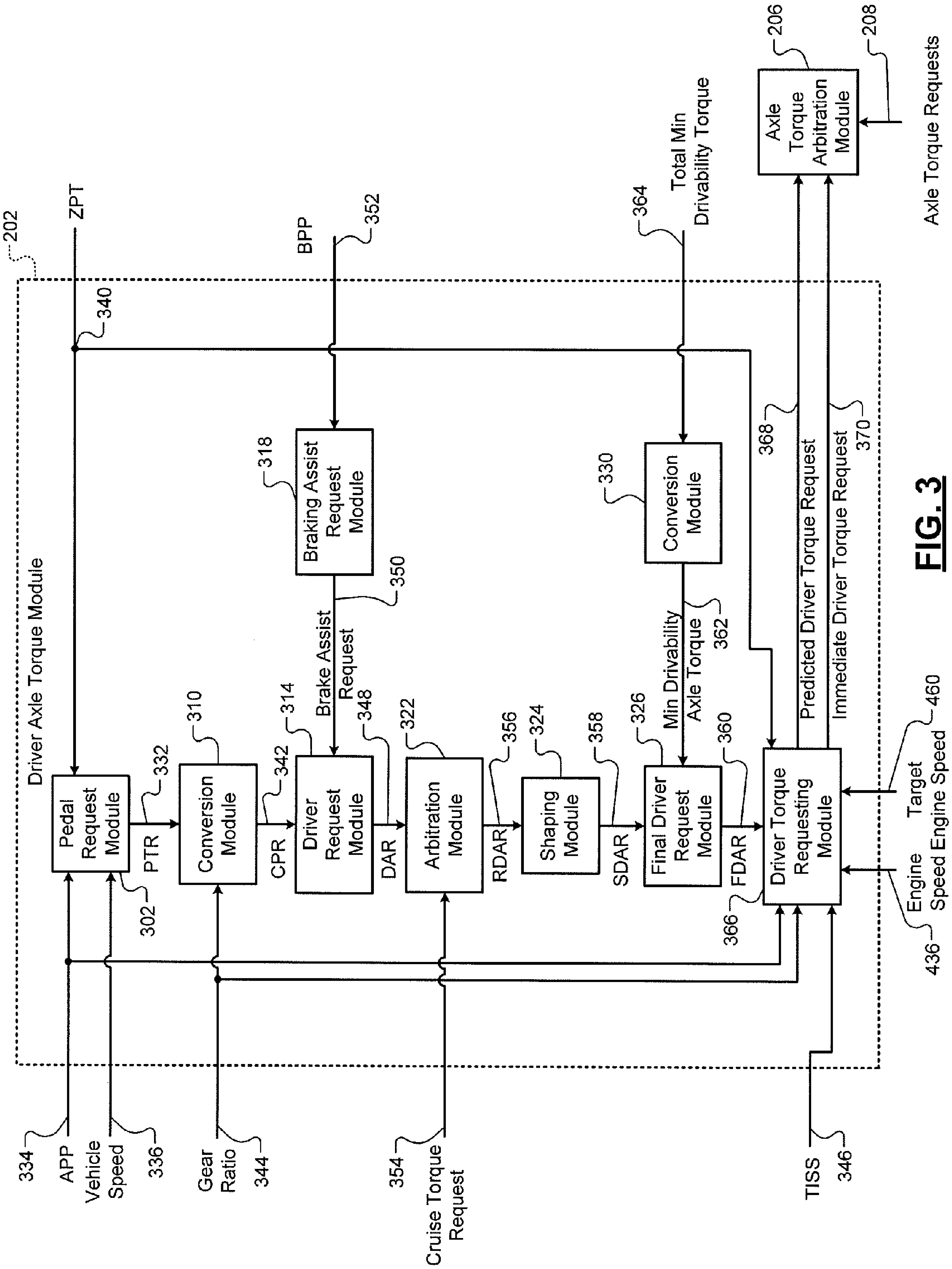

Engine Control Module
Boost Actuator Module
164
Throttle Actuator Module
116
Phaser Actuator Module
158
Spark Actuator Module
126
Cylinder Actuator Module
120
Fuel Actuator Module
124
Target Boost
260
Target Area
254
Target Intake
266
264
Target Exhaust
Target Spark
278
276
Target # Cylinders
282
280
Target Fueling
286
284
114
Boost Scheduling Module
258
Target MAP
252
Air Control Module
250
Target APC
256
Phaser Scheduling Module
262
Spark Control Module
Cylinder Control Module
Fuel Control Module
268
Spark Torque Request
270
Cylinder Torque Request
274
Fuel Torque Request
Air Torque Request
248
Torque Requesting Module
246
244
Reserves / Loads Module
242
238
220
224
240
Reserve/ Load Requests
Propulsion Torque Arbitration Module
218
Propulsion Torque Requests
214
Hybrid Control Module
196
Hybrid Optimization Module
216
212
210
Axle Torque Requests
Axle Torque Arbitration Module
206
208
202
204
Driver Axle Torque Module
Cruise Torque Request
Vehicle Speed
APP
Gear Ratio
BPP

FIG. 2



202
Driver Axle Torque Module
ZPT
340
BPP
352
364
Total Min Drivability Torque
206
Axle Torque Arbitration Module
208
Axle Torque Requests
Pedal Request Module
302
332
PTR
Conversion Module
310
342
CPR
Driver Request Module
314
348
DAR
Braking Assist Request Module
318
350
Brake Assist Request
Arbitration Module
322
356
RDAR
Shaping Module
324
358
SDAR
Final Driver Request Module
326
360
FDAR
Conversion Module
330
362
Min Drivability Axle Torque
Driver Torque Requesting Module
366
368
Predicted Driver Torque Request
370
Immediate Driver Torque Request
460
Target Engine Speed
436
Engine Speed
334
APP
Vehicle Speed
336
Gear Ratio
344
354
Cruise Torque Request
TISS
346


FIG. 3

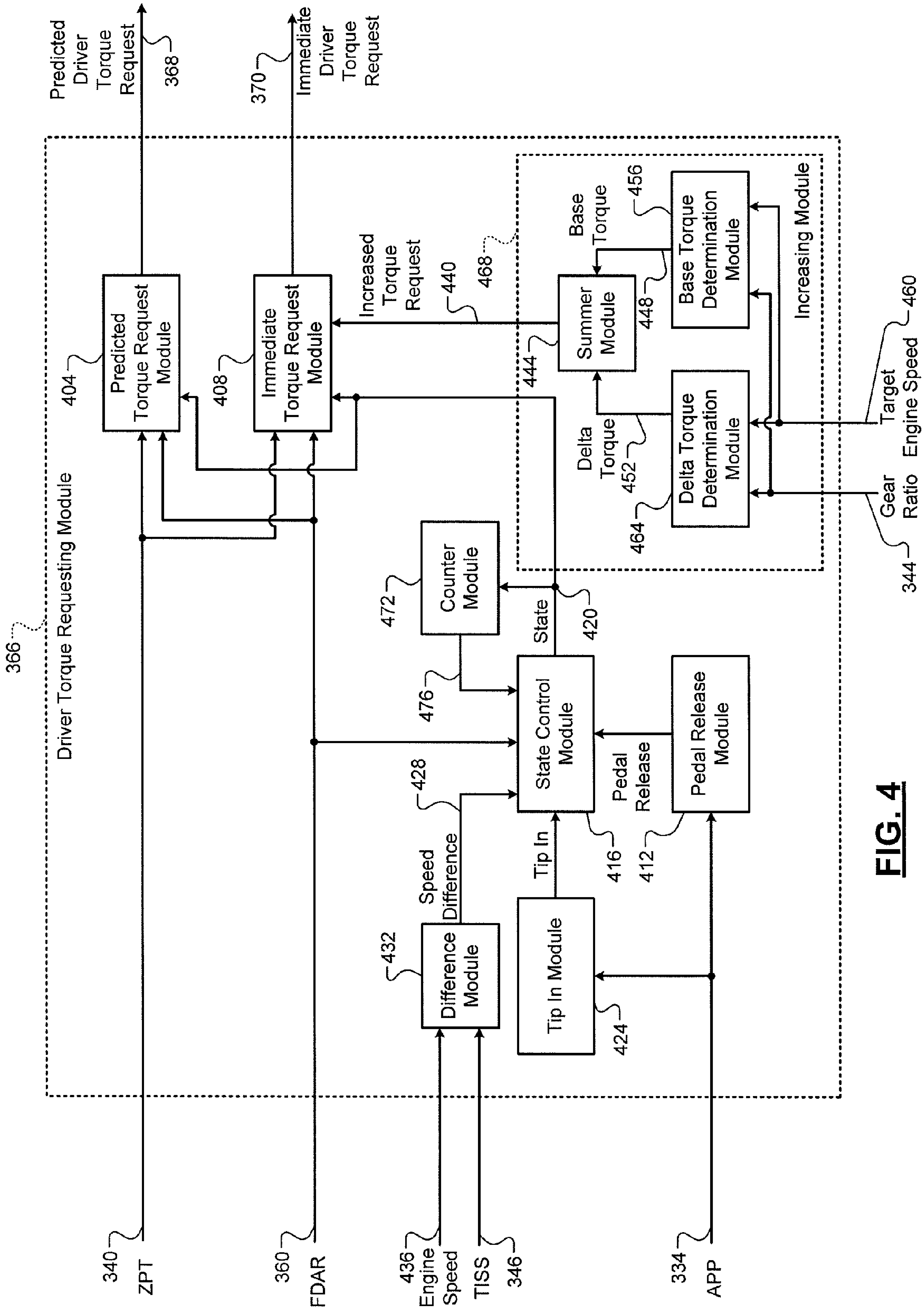

Predicted Driver Torque Request
368
370
Immediate Driver Torque Request
366
Driver Torque Requesting Module
404
Predicted Torque Request Module
408
Immediate Torque Request Module
Increased Torque Request
440
468
Base Torque
456
Base Torque Determination Module
448
Summer Module
444
Increasing Module
Delta Torque
452
Delta Torque Determination Module
464
460
Target Engine Speed
Gear Ratio
344
472
Counter Module
State
420
476
State Control Module
Pedal Release
Pedal Release Module
428
Speed Difference
Tip In
416
412
432
Difference Module
Tip In Module
424
340
ZPT
360
FDAR
436
Engine Speed
TISS
346
334
APP

FIG. 4

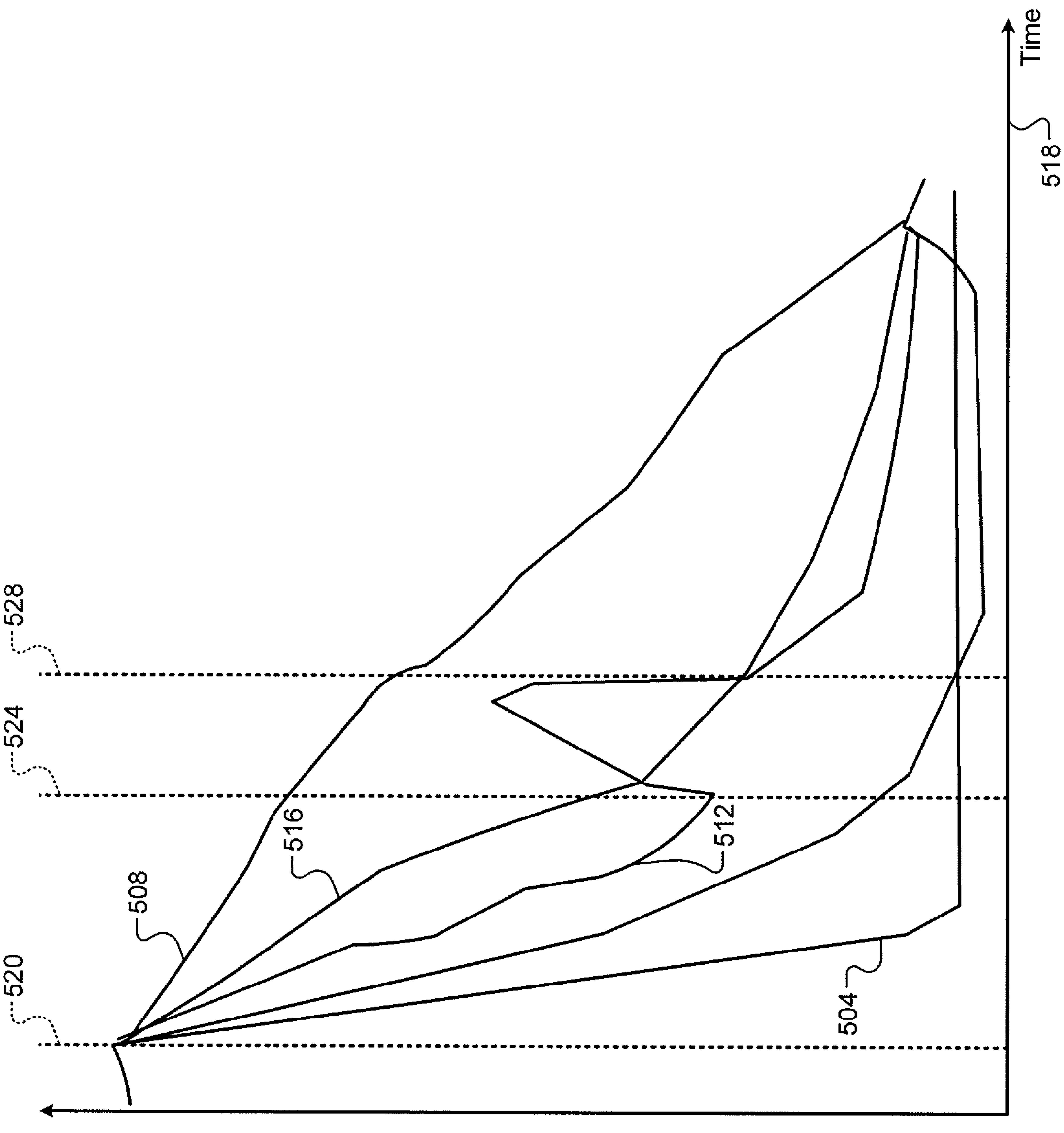



FIG. 5

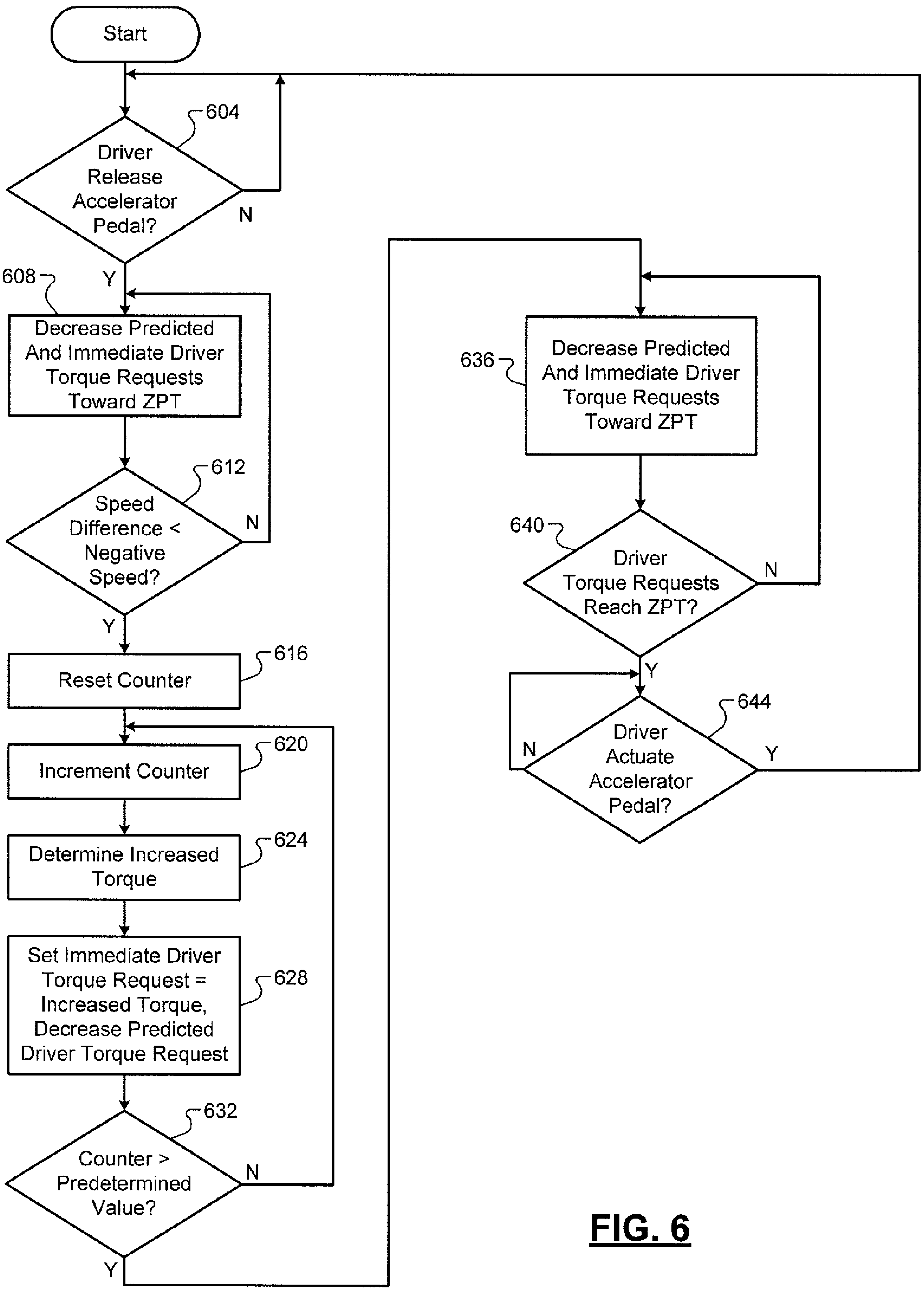

Start
604
Driver Release Accelerator Pedal?
N
Y
608
Decrease Predicted And Immediate Driver Torque Requests Toward ZPT
612
Speed Difference < Negative Speed?
N
Y
616
Reset Counter
620
Increment Counter
624
Determine Increased Torque
628
Set Immediate Driver Torque Request = Increased Torque, Decrease Predicted Driver Torque Request
632
Counter > Predetermined Value?
N
Y
636
Decrease Predicted And Immediate Driver Torque Requests Toward ZPT
640
Driver Torque Requests Reach ZPT?
N
Y
644
Driver Actuate Accelerator Pedal?
N
Y

FIG. 6

# ENGINE CONTROL SYSTEMS AND METHODS FOR ACCELERATOR PEDAL TIP-OUT

## FIELD

The present disclosure relates to internal combustion engines and more particularly to systems and methods for controlling an engine after a driver releases an accelerator pedal.

## BACKGROUND

The background description provided here is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

Internal combustion engines combust an air and fuel mixture within cylinders to drive pistons, which produces drive torque. Airflow into the engine is regulated via a throttle. More specifically, the throttle adjusts throttle area, which increases or decreases air flow into the engine. As the throttle area increases, the air flow into the engine increases. A fuel control system adjusts the rate that fuel is injected to provide a desired air/fuel mixture to the cylinders. Increasing the air and fuel to the cylinders increases the torque output of the engine.

Engine control systems have been developed to control engine torque output to achieve a desired predicted torque. Traditional engine control systems, however, do not control the engine torque output as accurately as desired. Further, traditional engine control systems do not provide as rapid of a response to control signals as is desired or coordinate engine torque control among various devices that affect engine torque output.

## SUMMARY

In a feature, a difference module determines a difference between an engine speed and a transmission input shaft speed. A state control module sets a signal to a first state when a driver releases an accelerator pedal and selectively transitions the signal from the first state to a second state when the difference is less than zero. An immediate torque request module decreases an engine torque request when the signal is in the first state and selectively increases the engine torque request when the signal is in the second state. At least one of: a spark control module that selectively adjusts spark timing based on the engine torque request; and a fuel control module that selectively adjusts fueling based on the engine torque request.

In further features, the difference module sets the difference equal to the engine speed minus the transmission input shaft speed.

In still further features, at least one of: the spark control module advances the spark timing when the engine torque request increases; and the fuel control module increases fueling when the engine torque request increases.

In yet further features, the state control module transitions the signal from the second state to a third state a predetermined period after transitioning the signal to the second state. The immediate torque request module decreases the engine torque request when the signal is in the third state.





In further features, the immediate torque request module decreases the engine torque request exponentially when the signal is in the third state.

In still further features, the immediate torque request module decreases the engine torque request at a first rate when the signal is in the first state and decreases the engine torque request at a second rate when the signal is in the third state.

In yet further features, an increasing module that determines an increased torque request based on a gear ratio and a target engine speed, and the immediate torque request module sets the engine torque request to the increased torque request when the signal is in the second state.

In further features, the increasing module determines a base torque based on the gear ratio and the target engine speed, determines a delta torque based on the gear ratio and a difference between the target engine speed and the engine speed, and determines the increased torque request based on the base torque and the delta torque.

In still further features, the increasing module sets the increased torque equal to the base torque plus the delta torque.

In yet further features, the state control module selectively transitions the signal from the first state to a second state when the difference is less than a predetermined speed that is less than zero.

In a feature, an engine control method includes: determining a difference between an engine speed and a transmission input shaft speed; setting a signal to a first state when a driver releases an accelerator pedal; selectively transitioning the signal from the first state to a second state when the difference is less than zero; decreasing an engine torque request when the signal is in the first state; selectively increasing the engine torque request when the signal is in the second state; and at least one of: selectively adjusting spark timing based on the engine torque request; and selectively adjusting fueling based on the engine torque request.

In further features, the engine control method further includes setting the difference equal to the engine speed minus the transmission input shaft speed.

In still further features, the engine control method further includes at least one of: advancing the spark timing when the engine torque request increases; and increasing fueling when the engine torque request increases.

In yet further features, the engine control method further includes: transitioning the signal from the second state to a third state a predetermined period after transitioning the signal to the second state; and decreasing the engine torque request when the signal is in the third state

In further features, the engine control method further includes decreasing the engine torque request exponentially when the signal is in the third state.

In still further features, the engine control method further includes: decreasing the engine torque request at a first rate when the signal is in the first state; and decreasing the engine torque request at a second rate when the signal is in the third state.

In still further features, the engine control method further includes: determining an increased torque request based on a gear ratio and a target engine speed; and setting the engine torque request to the increased torque request when the signal is in the second state.

In still further features, the engine control method further includes: determining a base torque based on the gear ratio and the target engine speed; determining a delta torque based on the gear ratio and a difference between the target engine speed and the engine speed; and determining the increased torque request based on the base torque and the delta torque.

In yet further features, the engine control method further includes setting the increased torque equal to the base torque plus the delta torque.

In further features, the engine control method further includes selectively transitioning the signal from the first state to a second state when the difference is less than a predetermined speed that is less than zero.

Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** is a functional block diagram of an example implementation of an engine system according to the present disclosure;

FIG. **2** is a functional block diagram of an example implementation of an engine control system according to the present disclosure;

FIG. **3** is a functional block diagram of an example implementation of a driver axle torque module according to the present disclosure;

FIG. **4** is a functional block diagram of an example driver torque requesting module according to the present disclosure;

FIG. **5** is an example graph of accelerator pedal position and various torque requests as functions of time; and

FIG. **6** is a flowchart depicting an example method of controlling immediate and predicted driver torque requests when a driver releases an accelerator pedal according to the present disclosure.

In the drawings, reference numbers may be reused to identify similar and/or identical elements.

## DETAILED DESCRIPTION

A control module of a vehicle controls torque output of an engine based on driver inputs, such as a position of an accelerator pedal. More specifically, the control module generates engine torque requests based on the driver inputs and controls engine actuators based on the engine torque requests. A transmission transfers torque from the engine to a driveline, and the driveline transfers torque to wheels of the vehicle.

The control module generally decreases the engine torque requests when the driver releases the accelerator pedal. Decreasing the engine torque requests decreases the torque output of the engine. When the driver releases the accelerator pedal, however, torque attributable to the vehicle's momentum is fed back to the engine via the driveline and the transmission. This torque may cause teeth of one or more sets of meshed gears to contact each other and produce sound and/or vibration.

To minimize or prevent sound and vibration from occurring after the driver releases the accelerator pedal, the control module of the present disclosure selectively increases an engine torque request when an engine speed is less than a transmission input shaft speed. The engine speed being less than the transmission input shaft speed indicates that sound and/or vibration may occur.

Increasing the engine torque requests increases the torque output of the engine and, therefore, increases the engine speed toward the transmission input shaft speed. Increasing the engine speed toward the transmission input shaft speed may minimize any sound and vibration that occurs when the teeth of the one or more sets of meshed gears contact each other.

Increasing the engine torque request to minimize sound and vibration may also enable the control module to rapidly decrease the engine torque request after the increase. The control module may, for example, decrease the engine torque request exponentially after increasing the engine torque request. Rapidly decreasing the engine torque request may enable one or more fuel consumption decreasing actions (e.g., fuel cutoff, deceleration fuel cutoff, and/or cylinder deactivation) to be taken as early as possible after the release of the accelerator pedal.

Referring now to FIG. **1**, a functional block diagram of an example engine system **100** is presented. The engine system **100** includes an engine **102** that combusts an air/fuel mixture to produce drive torque for a vehicle based on driver inputs from a driver input module **104**. The driver inputs may include, for example, one or more accelerator pedal positions (APPs) measured by APP sensors (not shown), one or more brake pedal positions (BPPs) measured by BPP sensors (not shown), and a cruise torque request provided by a cruise control system (not shown). In various implementations, the cruise control system may include an adaptive cruise control system that maintains a predetermined following distance. The driver inputs may also include a position of a park, reverse, neutral, drive lever (PRNDL) and other suitable inputs.

Air is drawn into an intake manifold **110** through a throttle valve **112**. For example only, the throttle valve **112** may include a butterfly valve having a rotatable blade. An engine control module (ECM) **114** controls a throttle actuator module **116**, and the throttle actuator module **116** regulates opening of the throttle valve **112** to control the amount of air drawn into the intake manifold **110**.

Air from the intake manifold **110** is drawn into one or more cylinders of the engine **102**. While the engine **102** may include more than one cylinder, for illustration purposes only a single representative cylinder **118** is shown. For example only, the engine **102** may include 2, 3, 4, 5, 6, 8, 10, and/or 12 cylinders. The ECM **114** may instruct a cylinder actuator module **120** to selectively deactivate (valves of) some or all of the cylinders, for example, to improve fuel efficiency in some circumstances.

The engine **102** may operate using a four-stroke engine cycle. The four strokes, described below, may be referred to as the intake stroke, the compression stroke, the combustion stroke, and the exhaust stroke. During each revolution of a crankshaft (not shown), two of the four strokes occur within the cylinder **118**. Therefore, two crankshaft revolutions may be necessary for the cylinder **118** to experience all four of the strokes of one engine cycle.

During the intake stroke, air from the intake manifold **110** is drawn into the cylinder **118** through an intake valve **122**. The ECM **114** controls a fuel actuator module **124**, which regulates fuel injection to achieve a target air/fuel ratio. Fuel may be injected into the intake manifold **110** at a central location or at multiple locations, such as near the intake valve(s) of each of the cylinders. In various implementations (not shown), fuel may be injected directly into the cylinders or into mixing chambers associated with the cylinders. The fuel actuator module **124** may halt injection of fuel to cylinders that are deactivated.

The injected fuel mixes with air and creates an air/fuel mixture. During the compression stroke, a piston (not shown) within the cylinder **118** compresses the air/fuel mixture. Based on a signal from the ECM **114**, a spark actuator module

126 energizes a spark plug **128** in the cylinder **118**, which ignites the air/fuel mixture. The timing of the spark may be specified relative to the time when the piston is at a topmost position, referred to as top dead center (TDC).

The spark actuator module **126** may be controlled by a timing signal specifying how far before or after TDC to generate the spark. Because the piston position is directly related to crankshaft rotation, operation of the spark actuator module **126** may be synchronized with crankshaft angle. In various implementations, the spark actuator module **126** may halt provision of spark to deactivated cylinders. While a spark ignition engine, the present disclosure is also applicable to other types of engines including compression combustion engines and other types of engines.

Combustion of the air/fuel mixture within a cylinder may be referred to as a firing event. The spark actuator module **126** may have the ability to vary the timing of the spark for each firing event. In addition, the spark actuator module **126** may have the ability to vary the spark timing for a given firing event even when a change in the timing signal is received after a firing event of a cylinder immediately before a given firing event.

During the combustion stroke, the combustion of the air/fuel mixture drives the piston away from the TDC position, thereby driving the rotation of the crankshaft. The combustion stroke may be defined as the time between the piston reaching TDC and the time at which the piston reaches a bottommost position, which may be referred to as bottom dead center (BDC). During the exhaust stroke, the piston moves toward the TDC position again and expels the byproducts of combustion through an exhaust valve **130**. The byproducts of combustion are exhausted from the vehicle via an exhaust system **134**.

The intake valve **122** may be controlled by an intake camshaft **140**, while the exhaust valve **130** may be controlled by an exhaust camshaft **142**. In various implementations, multiple intake camshafts (including the intake camshaft **140**) may control multiple intake valves (including the intake valve **122**) for the cylinder **118** and/or may control the intake valves (including the intake valve **122**) of multiple banks of cylinders (including the cylinder **118**). Similarly, multiple exhaust camshafts (including the exhaust camshaft **142**) may control multiple exhaust valves for the cylinder **118** and/or may control exhaust valves (including the exhaust valve **130**) for multiple banks of cylinders (including the cylinder **118**).

The cylinder actuator module **120** may disable opening of the intake valve **122** and/or the exhaust valve **130** of deactivated cylinders. In various other implementations, the intake valve **122** and/or the exhaust valve **130** may be controlled by devices other than camshafts, such as electromagnetic actuators.

The time at which the intake valve **122** is opened may be varied with respect to the TDC position by an intake cam phaser **148**. The time at which the exhaust valve **130** is opened may be varied with respect to the TDC position by an exhaust cam phaser **150**. A phaser actuator module **158** may control the intake cam phaser **148** and the exhaust cam phaser **150** based on signals from the ECM **114**. When implemented, variable valve actuation (WA) technologies (not shown) may also be controlled by the phaser actuator module **158**.

The engine system **100** may include a boost device that provides pressurized air to the intake manifold **110**. For example, FIG. **1** shows a turbocharger including a turbine **160-1** that is powered by hot exhaust gases flowing through the exhaust system **134**. The turbocharger also includes a cold air compressor **160-2**, driven by the turbine **160-1**, that compresses air leading into the throttle valve **112**. In various implementations, a supercharger (not shown), driven by the crankshaft, may compress air from the throttle valve **112** and deliver compressed air to the intake manifold **110**.

A wastegate **162** (e.g., a turbo bypass valve) may allow exhaust to bypass the turbine **160-1**, thereby reducing the boost provided by the turbocharger. The ECM **114** may control the boost of the turbocharger via a boost actuator module **164**. For example only, the boost actuator module **164** may modulate the boost of the turbocharger by controlling the position of the wastegate **162**. In various implementations, multiple turbochargers may be controlled by the boost actuator module **164**. The turbocharger may have variable geometry, which may be controlled by the boost actuator module **164**.

A cooler (e.g., an intercooler or a charge air cooler) (not shown) may dissipate some of the heat contained in the compressed air charge, which is generated as the air is compressed. The compressed air charge may also absorb heat from components of the exhaust system **134**. Although shown separated for purposes of illustration, the turbine **160-1** and the compressor **160-2** may be attached to each other near the location of the turbine **160-1**, placing intake air in close proximity to hot exhaust.

The engine system **100** may include an exhaust gas recirculation (EGR) valve **170** that selectively directs exhaust gas back to the intake manifold **110**. The EGR valve **170** may be located upstream of the turbine **160-1**. The EGR valve **170** may be controlled by an EGR actuator module **172**.

A position of the crankshaft may be measured using a crankshaft position sensor **178**. The ECM **114** may determine a rotational speed of the crankshaft in revolutions per minute (RPM) based on the crankshaft position. The rotational speed of the crankshaft may also be referred to as engine speed or engine output speed.

A vehicle speed sensor **180** may measure a speed of the vehicle. The vehicle speed may be determined based on, for example, a transmission output shaft speed (TOSS), one or more wheel speeds, or another suitable measure of the vehicle speed. Temperature of engine coolant may be measured using an engine coolant temperature (ECT) sensor **182**. The ECT sensor **182** may be located within the engine **102** or at other locations where the coolant is circulated, such as a radiator (not shown).

A pressure within the intake manifold **110** may be measured using a manifold absolute pressure (MAP) sensor **184**. In various implementations, engine vacuum may be measured, where engine vacuum includes a difference between ambient air pressure and the pressure within the intake manifold **110**. Mass air flowrate into the intake manifold **110** may be measured using a mass air flowrate (MAF) sensor **186**. In various implementations, the MAF sensor **186** may be located in a housing that also includes the throttle valve **112**. A transmission input shaft speed (TISS) sensor **188** may measure a rotational speed of a transmission input shaft.

The throttle actuator module **116** may monitor the position of the throttle valve **112** using one or more throttle position sensors (TPS) **190**. The temperature of air being drawn into the engine **102** may be measured using an intake air temperature (IAT) sensor **192**. In various implementations, the IAT may be used as an ambient air temperature. The ECM **114** may use signals from the sensors to make control decisions for the engine system **100**.

The ECM **114** may communicate with a transmission control module **194** to coordinate operation of the engine **102** with a transmission (not shown). For example only, the ECM **114** may reduce engine output torque for a gear shift within the transmission. Torque output by the engine **102** may be transferred to the transmission via one or more torque transmission devices (not shown), such as a torque converter.

The transmission control module **194** may also share data with the ECM **114**, such as a gear ratio selected within the transmission and a commanded state of a torque converter clutch (TCC) (not shown) of the torque converter. For example only, the state of the TCC may include a locked state or an unlocked state. The state of the TCC may be related to an amount of TCC slip. TCC slip may refer to a difference between the engine speed and the transmission input shaft speed. The TCC may be said to be in the locked state when the TCC slip is approximately zero. The TCC may also be said to be in the locked state when the TCC slip is being controlled to less than a predetermined slip (e.g., 15 revolutions per minute). The TCC may be said to be in the unlocked state when the TCC slip is greater than the predetermined slip.

The ECM **114** may also communicate with a hybrid control module **196** to coordinate operation of the engine **102** and an electric motor **198**. The electric motor **198** may also function as a generator, and may selectively be used to produce electrical energy for use by vehicle electrical systems and/or for storage in a battery. The electric motor **198** may also function as a starter to drive rotation of the crankshaft to startup the engine **102**. The electric motor **198** may also function as a motor to supplement/assist the engine **102**.

An engine actuator varies one or more engine parameters based on an associated target value. For example only, the throttle actuator module **116** may be referred to as an engine actuator and a target throttle opening may be the associated target value. In the example of FIG. **1**, the throttle actuator module **116** achieves the target throttle opening by adjusting opening of the throttle valve **112**.

Similarly, the spark actuator module **126** may be referred to as an engine actuator, while the associated target value may refer to a target amount of spark advance, for example, relative to cylinder TDC. Other engine actuators may include the cylinder actuator module **120**, the fuel actuator module **124**, the phaser actuator module **158**, the boost actuator module **164**, and the EGR actuator module **172**. For these engine actuators, the associated target values may include number of activated cylinders, fueling rate, intake and exhaust cam phaser angles, boost pressure, and EGR valve opening, respectively. The ECM **114** may control the target values in order to cause the engine **102** to generate a desired engine output torque and to achieve one or more other targets.

Referring now to FIG. **2**, a functional block diagram of an example engine control system is presented. An example implementation of the ECM **114** includes a driver axle torque module **202**. The driver axle torque module **202** may determine a final driver axle request and predicted and immediate driver (axle) torque requests **204** as discussed below in conjunction with the examples of FIGS. **3** and **4**.

An axle torque arbitration module **206** arbitrates between the driver axle torque requests **204** from the driver axle torque module **202** and other axle torque requests **208**. The other axle torque requests **208** may include, for example, torque requests generated to decease positive or negative wheel slip and/or other types of axle torque requests. Axle torque (torque at the wheels) may be produced by various sources including the engine **102** and/or the electric motor **198**.

The axle torque arbitration module **206** outputs a predicted (axle) torque request **210** and an immediate (axle) torque request **212** based on the results of arbitrating between the received torque requests. As described below, the predicted and immediate torque requests **210** and **212** may selectively be adjusted by other modules of the ECM **114** before being used to control the engine actuators.

In general terms, the immediate torque request **212** may be an amount of currently desired axle torque, while the predicted torque request **210** may be an amount of axle torque that may be needed on short notice. The ECM **114** controls the engine system **100** to produce an axle torque equal to the immediate torque request **212**. However, different combinations of target values may result in production of the same amount of axle torque.

The ECM **114** may therefore adjust one or more target values to enable a faster transition to the predicted torque request **210**, while still maintaining the axle torque at the immediate torque request **212**. In various implementations, the predicted torque request **210** may be set based on one or more driver torque requests. The immediate torque request **212** may be set to less than the predicted torque request **210** under some circumstances.

In general terms, the difference between the immediate torque request **212** and the predicted torque request **210** can be referred to as a torque reserve. The torque reserve may represent the amount of additional torque (above the immediate torque request **212**) that the engine system **100** can begin to produce with minimal delay. Fast engine actuators are used to increase or decrease current axle torque with minimal delay. Fast engine actuators are defined in contrast with slow engine actuators.

Generally speaking, fast engine actuators can change the engine torque output more quickly than slow engine actuators. Slow actuators may respond more slowly to changes in their respective target values than fast actuators do. For example, a slow actuator may include mechanical components that require time to move from one position to another in response to a change in target value. A slow actuator may also be characterized by the amount of time it takes for the engine torque to begin to change-once the slow actuator begins to implement the changed target value. Generally, this amount of time will be longer for slow actuators than for fast actuators. In addition, even after beginning to change, the engine torque may take longer to fully respond to a change in a slow actuator.

For example only, the spark actuator module **126** may be a fast actuator. Spark-ignition engines may combust fuels including, for example, gasoline and ethanol, by applying a spark. The fuel actuator module **124** may be a fast actuator in compression-ignition engines, such as diesel engines. By way of contrast, the throttle actuator module **116** may be a slow actuator.

As described above, the spark actuator module **126** can vary the spark timing for a next firing event when the spark timing is changed between a last firing event and the next firing event. By way of contrast, changes in throttle opening take longer to affect engine output torque. The throttle actuator module **116** changes the throttle opening by adjusting the angle of the blade of the throttle valve **112**.

Therefore, when the target value for opening of the throttle valve **112** is changed, there is a mechanical delay as the throttle valve **112** moves from its previous position to a new position in response to the change. In addition, air flow changes based on the throttle opening are subject to air transport delays in the intake manifold **110**. Further, increased air flow in the intake manifold **110** is not realized as an increase in engine output torque until the cylinder **118** receives additional air in the next intake stroke, compresses the additional air, and combustion including that additional air begins.

Using these actuators as an example, a torque reserve can be created by setting the throttle opening to a value that would allow the engine **102** to produce the predicted torque request **210**. Meanwhile, the spark timing can be set based on the immediate torque request **212**, which is less than the predicted torque request **210**. Although the throttle opening generates enough air flow for the engine **102** to produce the predicted torque request **210**, the spark timing is retarded (which reduces torque) based on the immediate torque request **212**. The engine **102** will therefore produce the immediate torque request **212**.

When additional torque is needed, the spark timing can be set based on the predicted torque request **210** or a torque between the predicted and immediate torque requests **210** and **212**. By the following firing event, the spark actuator module **126** may return the spark timing to an optimum value, which allows the engine **102** to produce the full engine output torque achievable with the air flow already present. The engine output torque may therefore be quickly increased to achieve the predicted torque request **210** without experiencing delays from changing the throttle opening.

The axle torque arbitration module **206** may output the predicted torque request **210** and the immediate torque request **212** to a propulsion torque arbitration module **214**. In various implementations, the axle torque arbitration module **206** may output the predicted and immediate torque requests **210** and **212** to a hybrid optimization module **216**.

The hybrid optimization module **216** may determine how much torque should be produced by the engine **102** and how much torque should be produced by the electric motor **198**. The hybrid optimization module **216** then outputs modified predicted and immediate torque requests (not numbered) to the propulsion torque arbitration module **214**. In various implementations, the hybrid optimization module **216** may be implemented in the hybrid control module **196**.

The predicted and immediate torque requests received by the propulsion torque arbitration module **214** are converted from an axle torque domain (torque at the wheels) into a propulsion torque domain (torque at the crankshaft). This conversion may occur before, after, as part of, or in place of the hybrid optimization module **216**.

The propulsion torque arbitration module **214** arbitrates between received propulsion torque requests to generate an arbitrated predicted torque request **220** and an arbitrated immediate torque request **224**. The arbitrated torque requests **220** and **224** may be generated by selecting a winning request from among received torque requests. Alternatively or additionally, the arbitrated torque requests may be generated by modifying one of the received requests based on another one or more of the received torque requests.

The received propulsion torque requests include the converted predicted and immediate torque requests and other propulsion torque requests. The received propulsion torque requests may also include other propulsion torque requests **218**. For example, the propulsion torque requests **218** may include torque reductions for engine over-speed protection, torque increases for stall prevention, torque reductions requested by the transmission control module **194** to accommodate gear shifts, and other types of propulsion torque requests.

A reserves/loads module **238** receives the arbitrated predicted and immediate torque requests **220** and **224**. Based on one or more reserve and/or torque load requests **240**, the reserves/loads module **238** may adjust the arbitrated predicted and immediate torque requests **220** and **224** to create a torque reserve, to adjust a torque reserve already present in the arbitrated predicted and immediate torque requests **220** and **224**, and/or to compensate for one or more torque loads on the engine **102**. The reserves/loads module **238** outputs adjusted predicted and immediate torque requests **242** and **244** to a torque requesting module **246**.

For example only, a catalyst light-off process or a cold start emissions reduction process may require retarded spark timing. The reserves/loads module **238** may therefore increase the adjusted predicted torque request **242** above the adjusted immediate torque request **244** to create retarded spark for the cold start emissions reduction process. In another example, the air/fuel ratio of the engine and/or the mass air flow may be directly varied, such as by diagnostic intrusive equivalence ratio testing and/or new engine purging. Before beginning these processes, a torque reserve may be created or increased to quickly offset decreases in engine output torque that result from leaning the air/fuel mixture during these processes.

The reserves/loads module **238** may also create or increase a torque reserve in anticipation of a future load, such as power steering pump operation or engagement of an air conditioning (A/C) compressor clutch. The reserve for engagement of the A/C compressor clutch may be created when the driver first requests air conditioning. The reserves/loads module **238** may increase the adjusted predicted torque request **242** while leaving the adjusted immediate torque request **244** unchanged to produce the torque reserve. Then, when the A/C compressor clutch engages, the reserves/loads module **238** may increase the adjusted immediate torque request **244** by the estimated load of the A/C compressor clutch.

The torque requesting module **246** receives the adjusted predicted and immediate torque requests **242** and **244**. The torque requesting module **246** determines how the adjusted predicted and immediate torque requests **242** and **244** will be achieved. The torque requesting module **246** may be engine type specific. For example, the torque requesting module **246** may be implemented differently or use different control schemes for spark-ignition engines versus compression-ignition engines.

In various implementations, the torque requesting module **246** may define a boundary between modules that are common across all engine types and modules that are engine type specific. For example, engine types may include spark-ignition and compression-ignition and other suitable types of engines. Modules prior to the torque requesting module **246**, such as the propulsion torque arbitration module **214**, may be common across engine types, while the torque requesting module **246** and subsequent modules may be engine type specific.

The torque requesting module **246** determines an air torque request **248** based on the adjusted predicted and immediate torque requests **242** and **244**. Target values for airflow controlling engine actuators are determined based on the air torque request **248**. For example, based on the air torque request **248**, an air control module **250** may determine a target MAP **252**, a target throttle opening **254**, and a target mass of air per cylinder (APC) **256**.

A boost control module **258** may determine a target boost **260** based on the target MAP **252**, and the boost actuator module **164** may control boost provided by the turbocharger based on the target boost **260**. The throttle actuator module **116** may control opening of the throttle valve **112** based on the target throttle opening **254**. A phaser scheduling module **262** may determine target intake and exhaust phase angles **264** and **266** based on the target APC **256**, and the phaser actuator module **158** may control phasing of the intake and exhaust valves based on the target intake and exhaust phase angles **264** and **266**. The air control module **250** may also determine one or more other target values for controlling one or more other airflow controlling engine actuators based on the air torque request **248**, such as for the EGR valve **170**.

The torque requesting module **246** may also generate a spark torque request **268**, a cylinder torque request **270**, and a fuel torque request **274** based on the predicted and immediate torque requests **242** and **244**. A spark control module **276** may determine a target spark timing **278** based on the spark torque request **268**. The spark actuator module **126** may provide spark based on the target spark timing **278**.

The cylinder torque request **270** may be used by a cylinder control module **280** to determine a target number of cylinders to deactivate **282**. In various implementations, a target number of cylinders to activate may be used. The cylinder actuator module **120** selectively activates and deactivates the valves of cylinders based on the target number **282**.

The cylinder control module **280** may also instruct a fuel control module **284** to stop providing fuel for deactivated cylinders and may instruct the spark control module **276** to stop providing spark for deactivated cylinders. The spark control module **276** may stop providing spark to a cylinder once an fuel/air mixture that is already present in the cylinder has been combusted.

The fuel control module **284** may vary the amount of fuel provided to each cylinder based on the fuel torque request **274**. More specifically, the fuel control module **284** may generate target fueling parameters **286** based on the fuel torque request **274**. The target fueling parameters **286** may include, for example, target mass of fuel, target injection starting timing, and target number of fuel injections.

Referring now to FIG. **3**, a functional block diagram of an example implementation of the driver axle torque module **202** is presented. The driver axle torque module **202** may include a pedal request module **302**, a conversion module **310**, and a driver request module **314**. The driver axle torque module **202** may also include a braking assist request module **318**, an arbitration module **322**, a shaping module **324**, a final driver request module **326**, and a conversion module **330**.

The pedal request module **302** determines a pedal torque request (PTR) **332**. The PTR **332** may be generated in the propulsion torque domain, that is, in terms of torque at the crankshaft. In other words, the PTR **332** may be a propulsion torque request. The pedal request module **302** may determine the PTR **332** based on an APP **334**, a vehicle speed **336**, a zero pedal torque (ZPT) **340**, ambient air conditions (e.g., pressure and/or temperature), and/or one or more other suitable parameters. The APP **334** may be, for example, measured using one or more APP sensors. The vehicle speed **336** may be measured, for example, using the vehicle speed sensor **180** or obtained in another suitable manner. The ZPT **340** may refer to a minimum amount of torque that the engine **102** can produce without stalling under the current operating conditions.

The conversion module **310** converts the PTR **332** into the axle torque domain (that is, in terms of torque at the wheels or axles) to produce a converted pedal request (CPR) **342**. In other words, the CPR **342** may be an axle torque request. The conversion module **310** may convert the PTR **332** based on, for example, drivetrain losses, a gear ratio **344**, one or more torque ratios, and/or one or more other suitable parameters. The gear ratio **344** may refer to a total (speed) ratio provided by the transmission and other driveline components. For example, the gear ratio **344** may correspond to a ratio of a TISS (transmission input shaft speed) **346** to a speed of one or more driveshafts.

The driver request module **314** determines a driver axle request (DAR) **348** based on the CPR **342**. The DAR **348** is in the axle torque domain. The driver request module **314** may determine the DAR **348** further based on a braking assist torque request **350**. For example only, the driver request module **314** may determine the DAR **348** using the equation:

$$DAR = CPR - BAR,$$

where DAR is the DAR **348** (e.g., Nm), CPR is the CPR **342** (e.g., Nm), and BAR is the braking assist torque request **350** (e.g., Nm).

The braking assist request module **318** may determine the braking assist torque request **350** and provide the braking assist torque request to the driver request module **314**. The braking assist torque request **350** may refer to a decrease in the engine output torque attributable to regenerative braking by the electric motor **198** requested to assist the mechanical brakes of the vehicle during vehicle braking. Performing regenerative braking generates electrical power and allows a reduced amount of mechanical braking to be used. The braking assist request module **318** may determine the braking assist request based on a BPP **352**. The hybrid control module **196** or the hybrid optimization module **216** may control regenerative braking performed by the electric motor **198** based on the braking assist torque request **350**. The BPP **352** may be, for example, measured using one or more BPP sensors.

The arbitration module **322** receives the DAR **348** and other driver torque requests and arbitrates between the received requests. For example only, the arbitration module **322** may arbitrate between the DAR **348** and a cruise torque request **354**. The cruise torque request **354** may correspond to a torque request generates by a cruise control system. The cruise control system may generate the cruse torque request **354**, for example, to adjust the vehicle speed **336** toward a target vehicle speed. The arbitration module **322** outputs the winner of the arbitration as a raw driver axle request (RDAR) **356** (e.g., Nm). The RDAR **356** is in the axle torque domain.

The shaping module **324** selectively shapes the RDAR **356** to produce a shaped driver axle request (SDAR) **358**. For example only, the shaping module **324** may apply one or more filters to the RDAR **356** to generate the SDAR **358**. The SDAR **358** is in the axle torque domain.

The final driver request module **326** generates a final driver axle request (FDAR) **360** based on the SDAR **358**. The final driver request module **326** may selectively limit the FDAR **360** to a minimum drivability axle torque **362**. In other words, the final driver request module **326** may set the FDAR **360** equal to the SDAR **358** when the SDAR **358** is greater than the minimum drivability axle torque **362**. When the SDAR **358** is less than the minimum drivability axle torque **362**, the final driver request module **326** may set the FDAR **360** equal to the minimum drivability axle torque **362**. The minimum drivability axle torque **362** may correspond to a minimum amount of axle torque selected to maintain vehicle drivability (e.g., prevent engine stalling).

The conversion module **330** may determine the minimum drivability axle torque **362** based on a total minimum drivability torque **364**. More specifically, the conversion module **330** may convert the total minimum drivability torque **364** from the propulsion torque domain into the axle torque domain to produce the minimum drivability axle torque **362**. The conversion may be similar or identical to the conversion performed by the conversion module **310**. The total minimum drivability torque may refer to an amount of torque (e.g., Nm) at the crankshaft selected to maintain the vehicle drivability.

A driver torque requesting module **366** generates predicted and immediate driver torque requests **368** and **370** (collectively illustrated in FIG. **2** by reference numeral **204**). The predicted and immediate driver torque requests **368** and **370** are provided to the axle torque arbitration module **206** for arbitration with the other axle torque requests, as discussed above. Generation of the predicted and immediate driver torque requests **368** and **370** is discussed further below.

Referring now to FIG. **4**, a functional block diagram of an example implementation of the driver torque requesting module **366** is presented. A predicted torque request module **404** generates the predicted driver torque request **368**. An immediate torque request module **408** generates the immediate driver torque request **370**.

Generally, the predicted and immediate torque request modules **404** and **408** generate the predicted and immediate driver torque requests **368** and **370** based on the FDAR **360**. However, when the driver releases the accelerator pedal, the driver may experience sound and/or vibration. The sound and/or vibration may occur when teeth of meshed gears (e.g., of the transmission and/or other driveline components) contact each other after the driver releases the accelerator pedal and the vehicle's momentum is fed back to the engine **102** via the transmission and other driveline components. The driver releasing the accelerator pedal may also be referred to as a tip out event.

To minimize or prevent sound and/or vibration from occurring after the driver releases the accelerator pedal, the predicted and immediate driver torque requests **368** and **370** could be decreased to the ZPT **340** at a rate that is slow enough to prevent or minimize sound and/or vibration. While slowly decreasing the predicted and immediate driver torque requests **368** and **370** may effectively minimize or prevent sound and/or vibration, the predicted and/or immediate driver torque requests **368** and **370** may be decreased to the ZPT **340** more quickly while still minimizing sound and/or vibration.

The immediate torque request module **408** therefore more quickly decreases the immediate driver torque request **370** after the driver releases the accelerator pedal. When a difference between an engine speed and a TISS is negative after the driver releases the accelerator pedal, the immediate torque request module **408** increases the immediate driver torque request **370**. The difference being negative indicates that teeth of meshed gears may contact each other and, therefore, that sound and/or vibration may occur.

Increasing the immediate driver torque request **370** causes an increase in the engine torque output (for example via adjusting spark timing, fueling, and/or one or more other fast actuators), thereby increasing the engine speed toward the TISS. Increasing the engine speed toward the TISS decreases may minimize or prevent sound and/or vibration from occurring.

A pedal release module **412** indicates when the driver has released the accelerator pedal based on the APP **334**. For example, the pedal release module **412** may indicate that the driver has released the accelerator pedal when the APP **334** is less than a first predetermined position. For example only, the first predetermined position may be approximately 5 percent actuated from a resting (non-actuated) APP or another suitable position. Additionally or alternatively, the pedal release module **412** may indicate that the driver has released the accelerator pedal when a decrease in the APP **334** is greater than a predetermined amount, such as approximately 20-30 percent or another suitable amount.

A state control module **416** transitions a state signal **420** from an initial state to a first state when the pedal release module **412** indicates that the driver has released the accelerator pedal. The state control module **416** may alternatively transition the state signal **420** from the initial state to the first state when the FDAR **360** is less than a predetermined torque (e.g., 0 Newton meters or less) or decreases by at least a predetermined amount (e.g., approximately 50-60 Newton meters). The state control module **416** may require that the driver actuate the accelerator pedal before allowing the state signal **420** to be transitioned to the first state.

A tip in module **424** may indicate that the driver has actuated the accelerator pedal based on the APP **334**. For example, the tip in module **424** may indicate that the driver has actuated the accelerator pedal when the APP **334** is greater than a second predetermined position. The second predetermined position may be greater than or equal to the first predetermined position.

When the state signal **420** is in the initial state, the predicted and immediate torque request modules **404** and **408** may set the predicted and immediate driver torque requests **368** and **370**, respectively, based on the FDAR **360**. When the state signal **420** is in the first state, the predicted and immediate torque request modules **404** and **408** decrease the predicted and immediate driver torque requests **368** and **370** toward the ZPT **340**. The predicted and immediate torque request modules **404** and **408** may decrease the predicted and immediate driver torque requests **368** and **370**, respectively, at the same or different rates. Decreasing the predicted and immediate driver torque requests **368** decreases the amount of torque produced by the engine **102** as requested by the driver via releasing the accelerator pedal. The rates at which the predicted and immediate torque request modules **404** and **408** decrease the predicted and immediate driver torque requests **368** and **370** may be fixed or variable values.

The state control module **416** monitors a speed difference **428** while the state signal **420** is in the first state. A difference module **432** may set the speed difference **428** based on a difference between an engine speed **436** and the TISS **346**. For example, the difference module **432** may set the speed difference **428** equal to the engine speed **436** minus the TISS **346**. The engine speed **436** may be measured using the crankshaft position sensor **178**. The TISS **346** may be measured using the TISS sensor **188**. The speed difference **428** may also be referred to as a slip value.

When the speed difference **428** is less than a predetermined negative speed and the state signal **420** is in the first state, the state control module **416** may transition the state signal **420** from the first state to a second state. The predetermined negative speed is negative and may be, for example, approximately −100 RPM or another suitable negative speed. The speed difference **428** becoming less than the predetermined negative speed after the driver releases the accelerator pedal may indicate that sound and/or vibration may occur.

If a predetermined period passes after the predicted and immediate torque request modules **404** and **408** begin decreasing the predicted and immediate driver torque requests **368** and **370** and the speed difference **428** does not become less than the predetermined negative speed, the state control module **416** may transition the state signal **420** back to the initial state. Sound and/or vibration may not occur when the speed difference **428** does not become less than the predetermined negative speed within the predetermined period after the driver releases the accelerator pedal. The predetermined period may be, for example, approximately 0.5-1.0 seconds or another suitable period.

When the state signal **420** is in the second state, immediate torque request module **408** increases the immediate driver torque request **370**. For example, the immediate torque request module **408** may set the immediate driver torque request **370** to an increased torque request **440** when the state signal **420** is in the second state. The increased torque request **440** is greater than the immediate driver torque request **370** at the time when the state signal **420** is transitioned to the second state. The predicted torque request module **404** may decrease, maintain, or increase the predicted driver torque request **368** when the state signal **420** is in the second state.

A summer module **444** may set the increased torque request **440** based on a base torque **448** and a delta torque **452**. For example, the summer module **444** may set the increased torque equal to a sum of the base torque **448** and the delta torque **452**. The increased torque request **440** increases the torque output of the engine **102** to increase the engine speed toward the TISS **346** and thereby minimize sound and/or vibration when teeth of gears of the driveline contact each other.

A base torque determination module **456** may determine the base torque **448** based on the gear ratio **344** and a target engine speed **460**. The target engine speed **460** may be set to greater than the engine speed **436**, such as to or based on the TISS **346**, to adjust the speed difference **428** toward zero. The base torque determination module **456** may determine the base torque **448**, for example, using one of a mapping and a function that relates the gear ratio **344** and the target engine speed **460** to the base torque **448**. The mapping or function used to determine the base torque **448** may be calibrated such that the base torque **448** is greater than the immediate driver torque request **370** would have been had the immediate torque request module **408** continued to decrease the immediate driver torque request **370**.

A delta torque determination module **464** may determine the delta torque **452**. The delta torque determination module **464** may determine the delta torque **452** based on the gear ratio **344** and a difference between the target engine speed **460** and the engine speed **436**. As stated above, the target engine speed **460** may be set to greater than the engine speed **436**, such as to or based on the TISS **346**, to adjust the speed difference **428** toward zero. The delta torque determination module **464** may determine the delta torque **452**, for example, using one of a mapping and a function that relates the gear ratio **344** and the difference between the target engine speed **460** and the engine speed **436** to the delta torque **452**.

In various implementations, an increasing module **468** may be implemented and generate the increased torque request **440** based on the gear ratio **344**, the target engine speed **460**, and the engine speed **436**. For example, the increasing module **468** may determine the increased torque request **440**, for example, using one of a mapping and a function that relates the gear ratio **344**, the target engine speed **460**, and the difference between the target engine speed **460** and the engine speed **436** to the increased torque request **440**. Under some circumstances, the increasing module **468** may set the increased torque request **440** to a predetermined value. For example only, the increasing module **468** may set the increased torque request **440** to the immediate driver torque request **370** while the state signal **120** is in the first state during a period before the state signal **420** is transitioned to the second state or when the state signal **420** is in the second state.

Setting the immediate driver torque request **370** to the increased torque request **440** when the state signal **420** is in the second state increases the torque output of the engine **102**, for example, via adjusting the spark timing and/or fueling. The increased torque output increases the engine speed **436** to toward the TISS **346**, thereby minimizing sound and/or vibration that occurs when teeth of meshed gears contact each other.

A counter module **472** may reset a counter value **476** when the state signal **420** transitions to the second state. The counter module **472** may increment the counter value **476** every predetermined period when the state signal **420** is in the second state. In this manner, the counter module **472** tracks the period elapsed since the immediate torque request module **408** started increasing the immediate driver torque request **370**. The predetermined period may correspond to a rate at which the modules of the driver torque request module **366** update their outputs, such as approximately 3 milliseconds (ms) or another suitable period. While use of the counter module **472** and the counter value **476** is discussed, a timer and a period may be used alternatively.

When the counter value **476** is greater than a predetermined value, the state control module **416** transitions the state signal **420** from the second state to a third state. The predetermined value corresponds to a predetermined period for increasing torque to minimize sound and/or vibration and may be, for example, approximately 60-120 ms or another suitable period.

The predicted and immediate torque request modules **404** and **408** decrease the predicted and immediate driver torque requests **368** and **370** toward the ZPT **340** when the state signal **420** is in the third state. For example, the predicted and immediate torque request modules **404** and **408** may decrease the predicted and immediate driver torque requests **368** and **370** exponentially beginning when the state signal is transitioned to the third state. Decreasing the predicted and immediate driver torque requests **368** and **370** at faster rates may enable one or more fuel savings actions (e.g., fuel cutoff, deceleration fuel cutoff, and/or cylinder deactivation) to be taken sooner than if the predicted and immediate driver torque requests **368** and **370** were decreased at rates that are slow enough to prevent or minimize sound and/or vibration.

FIG. **5** includes an example graph of an accelerator pedal position **504**, an example predicted driver torque request **508**, an example immediate driver torque request **512**, and a purely decreased immediate driver torque request **516** as functions of time **518**. The driver releases the accelerator pedal at approximately time **520**, and the accelerator pedal position **504** therefore decreases.

The predicted and immediate torque request modules **404** and **408** decrease the predicted and immediate driver torque requests **368** and **370**, respectively, after the driver releases the accelerator pedal. The purely decreasing immediate torque request **516** could be used to prevent sound and/or vibration from occurring.

The speed difference **428** becomes less than the predetermined negative speed at approximately time **524**. The immediate torque request module **408** therefore increases the immediate driver torque request **370** to minimize sound and/or vibration. The example immediate driver torque request **512** includes an example of such an increase after time **524**.

The immediate torque request module **408** may increase the immediate driver torque request **370** for the predetermined period (e.g., approximately 60-120 ms) after the speed difference **428** becomes less than the predetermined negative speed. The predetermined period may end at approximately time **528**. The immediate torque request module **408** may begin decreasing the immediate driver torque request **370** more rapidly, such as based on a predetermined exponential decrease. The example immediate driver torque request **512** includes an example exponential decrease after time **528**.

Referring now to FIG. **6**, a flowchart depicting an example method of setting the predicted and immediate driver torque requests **368** and **370** when the driver releases the accelerator pedal is presented. Control may begin with **604** where the pedal release module **412** determines whether the driver has released the accelerator pedal. If **604** is true, control continues with **608**. If **604** is false, control may remain at **604**. The pedal release module **412** may determine that the driver has released the accelerator pedal, for example, when the APP

334 is less than a predetermined position or the APP 334 decreases by more than a predetermined amount.

At 608, the predicted and immediate torque request modules 404 and 408 decrease the predicted and immediate driver torque requests 368 and 370, respectively, toward the ZPT 340. The predicted and immediate torque request modules 404 and 408 may decrease the predicted and immediate driver torque requests 368 and 370, respectively, at the same or different rates.

At 612, the state control module 416 determines whether the speed difference 428 is less than the predetermined negative speed. If 612 is true, control continues with 616. If 612 is false, control may return to 608 to continue decreasing the predicted and immediate driver torque requests 368 and 370. The predetermined speed may be, for example, approximately −100 RPM or another suitable speed that indicates that sound and/or vibration may occur. If the speed difference 428 does not become less than the predetermined negative speed within a predetermined period (e.g., approximately 0.5-1.0 seconds) after the driver releases the accelerator pedal, the predicted and immediate torque request modules 404 and 408 may continue decreasing the predicted and immediate driver torque requests 368 and 370 toward the ZPT 340 and control may transfer to 644, which is discussed further below.

The counter module 472 resets the counter value 476 at 616 and increments the counter value 476 at 620. At 624, the increasing module 468 may determine the increased torque request 440 based on the gear ratio 344 and the target engine speed 460. For example, the base and delta torque determination modules 456 and 464 may determine the base and delta torques 448 and 452 based on the gear ratio, the target engine speed 460, and/or the difference between the target engine speed 460 and the engine speed 436, and the summer module 444 may set the increased torque request 440 to a sum of the base and delta torques 448 and 452. The predicted torque request module 404 may decrease, maintain, or increase the predicted driver torque request 368 at 628.

At 632, the state control module 416 determines whether the counter value 476 is greater than a predetermined value. The predetermined value corresponds to a predetermined period, such as approximately 60-120 ms or another suitable predetermined period. If 632 is true, control continues with 636. If 632 is false, control returns to 620 to continue using the increased torque request 440.

The predicted and immediate torque request modules 404 and 408 decrease the predicted and immediate driver torque requests 368 and 370, respectively, toward the ZPT 340 at 636. Decreases in the predicted and immediate driver torque requests 368 and 370 made at 636 may be made such that the predicted and immediate driver torque requests 368 and 370 are decreased based on a predetermined exponential curve over time. Decreasing the predicted and immediate driver torque requests 368 and 370 exponentially may enable one or more fuel savings actions to be taken sooner, such as fuel cutoff, deceleration fuel cutoff, and/or cylinder deactivation.

At 640, the state control module 416 may determine whether the predicted and immediate driver torque requests 368 and 370 are approximately equal to the ZPT 340. If 640 is true, control may continue with 644. If 640 is false, control may return to 636 to continue decreasing the predicted and immediate driver torque requests 368 and 370 toward the ZPT 340. At 644, the state control module 416 may determine whether the driver has actuated the accelerator pedal. If 644 is true, control may return to 604 to wait for another tip out event. If 644 is false, control may remain at 644. While determination of whether the driver has actuated the accelerator pedal at 644 is shown, if the driver actuates the accelerator pedal between 608 and 640, control may also return to 604.

The foregoing description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A or B or C), using a non-exclusive logical OR. It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure.

In this application, including the definitions below, the term module may be replaced with the term circuit. The term module may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC); a digital, analog, or mixed analog/digital discrete circuit; a digital, analog, or mixed analog/digital integrated circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor (shared, dedicated, or group) that executes code; memory (shared, dedicated, or group) that stores code executed by a processor; other suitable hardware components that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip.

The term code, as used above, may include software, firmware, and/or microcode, and may refer to programs, routines, functions, classes, and/or objects. The term shared processor encompasses a single processor that executes some or all code from multiple modules. The term group processor encompasses a processor that, in combination with additional processors, executes some or all code from one or more modules. The term shared memory encompasses a single memory that stores some or all code from multiple modules. The term group memory encompasses a memory that, in combination with additional memories, stores some or all code from one or more modules. The term memory may be a subset of the term computer-readable medium. The term computer-readable medium does not encompass transitory electrical and electromagnetic signals propagating through a medium, and may therefore be considered tangible and non-transitory. Non-limiting examples of a non-transitory tangible computer readable medium include nonvolatile memory, volatile memory, magnetic storage, and optical storage.

The apparatuses and methods described in this application may be partially or fully implemented by one or more computer programs executed by one or more processors. The computer programs include processor-executable instructions that are stored on at least one non-transitory tangible computer readable medium. The computer programs may also include and/or rely on stored data.

What is claimed is:

1. An engine control system of a vehicle, comprising:

a difference module that determines a difference between an engine speed and a transmission input shaft speed;

a state control module that sets a signal to a first state when a driver releases an accelerator pedal and that selectively transitions the signal from the first state to a second state when the difference is less than zero;

an immediate torque request module that decreases an engine torque request when the signal is in the first state and that selectively increases the engine torque request when the signal is in the second state; and

at least one of:

a spark control module that selectively adjusts spark timing based on the engine torque request; and

a fuel control module that selectively adjusts fueling based on the engine torque request.

**2**. The engine control system of claim **1** wherein the difference module sets the difference equal to the engine speed minus the transmission input shaft speed.

**3**. The engine control system of claim **1** wherein at least one of:

the spark control module advances the spark timing when the engine torque request increases; and

the fuel control module increases fueling when the engine torque request increases.

**4**. The engine control system of claim **1** wherein:

the state control module transitions the signal from the second state to a third state a predetermined period after transitioning the signal to the second state; and

the immediate torque request module decreases the engine torque request when the signal is in the third state.

**5**. The engine control system of claim **4** wherein the immediate torque request module decreases the engine torque request exponentially when the signal is in the third state.

**6**. The engine control system of claim **4** wherein the immediate torque request module decreases the engine torque request at a first rate when the signal is in the first state and decreases the engine torque request at a second rate when the signal is in the third state.

**7**. The engine control system of claim **1** further comprising an increasing module that determines an increased torque request based on a gear ratio and a target engine speed,

wherein the immediate torque request module sets the engine torque request to the increased torque request when the signal is in the second state.

**8**. The engine control system of claim **7** wherein the increasing module determines a base torque based on the gear ratio and the target engine speed, determines a delta torque based on the gear ratio and a difference between the target engine speed and the engine speed, and determines the increased torque request based on the base torque and the delta torque.

**9**. The engine control system of claim **8** wherein the increasing module sets the increased torque equal to the base torque plus the delta torque.

**10**. The engine control system of claim **1** wherein the state control module selectively transitions the signal from the first state to the second state when the difference is less than a predetermined speed that is less than zero.

**11**. An engine control method for a vehicle, comprising:

determining a difference between an engine speed and a transmission input shaft speed;

setting a signal to a first state when a driver releases an accelerator pedal;

selectively transitioning the signal from the first state to a second state when the difference is less than zero;

decreasing an engine torque request when the signal is in the first state;

selectively increasing the engine torque request when the signal is in the second state; and

at least one of:

selectively adjusting spark timing based on the engine torque request; and

selectively adjusting fueling based on the engine torque request.

**12**. The engine control method of claim **11** further comprising setting the difference equal to the engine speed minus the transmission input shaft speed.

**13**. The engine control method of claim **11** further comprising at least one of:

advancing the spark timing when the engine torque request increases; and

increasing fueling when the engine torque request increases.

**14**. The engine control method of claim **11** further comprising:

transitioning the signal from the second state to a third state a predetermined period after transitioning the signal to the second state; and

decreasing the engine torque request when the signal is in the third state.

**15**. The engine control method of claim **14** further comprising decreasing the engine torque request exponentially when the signal is in the third state.

**16**. The engine control method of claim **14** further comprising:

decreasing the engine torque request at a first rate when the signal is in the first state; and

decreasing the engine torque request at a second rate when the signal is in the third state.

**17**. The engine control method of claim **11** further comprising:

determining an increased torque request based on a gear ratio and a target engine speed; and

setting the engine torque request to the increased torque request when the signal is in the second state.

**18**. The engine control method of claim **17** further comprising:

determining a base torque based on the gear ratio and the target engine speed;

determining a delta torque based on the gear ratio and a difference between the target engine speed and the engine speed; and

determining the increased torque request based on the base torque and the delta torque.

**19**. The engine control method of claim **18** further comprising setting the increased torque equal to the base torque plus the delta torque.

**20**. The engine control method of claim **11** further comprising selectively transitioning the signal from the first state to the second state when the difference is less than a predetermined speed that is less than zero.

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